

Development of a measure of multiple physical environmental deprivation. After United Kingdom and New Zealand, Portugal

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Background: Spatial inequalities in health have been identified, but the contribution of physical environment has been largely ignored. In Portugal, strong spatial differences in morbidity and mortality remain unexplained. Based on previous United Kingdom (UK) and New Zealand (NZ) research, we aimed to develop a Portuguese measure of multiple environmental deprivation (PT-MEDIx) to assist in understanding spatial inequalities in health. **Methods:** PT-MEDIx was built at municipality level in four stages: (i) identify health-relevant environmental factors; (ii) acquire datasets about selected environmental factors and calculate municipality-level measures using Geographical Information Systems; (iii) test associations between selected environmental factors and mortality using negative binomial models, adjusting for age, sex, socioeconomic deprivation and interactions and (iv) construct a summary measure and assess its association with mortality. **Results:** We included five dimensions of the physical environment: air pollution, climate, drinking water quality, green space availability and industry proximity. PT-MEDIx score ranged from –1 (least environmental deprivation) to +4 (most) and depicted a clear spatial pattern: least deprived municipalities in the depopulated rural areas and most deprived in urban and industrial settings. Comparing with those in the intermediate category of environment deprivation, less deprived municipalities showed lower mortality rate ratios (MRRs) and vice versa: MRRs for all-cause mortality were 0.962 (95% confidence interval: 0.934–0.991) and 1.209 (1.086–1.344), in the least and most deprived municipalities, respectively, and for cancer, 0.957 (0.911–1.006) and 1.345 (1.123–1.598). **Conclusions:** The methods used to create UK and NZ indexes have good transferability to Portugal. MEDIx might contribute to untangle the complex pathways that link health, socioeconomic and physical environment.

Introduction

Spatial inequalities in health and health-related behaviours have been identified worldwide.¹ Reducing health inequalities is currently a political priority,² yet spatial inequalities in health are widening rather than narrowing.³ However, individual-level characteristics and area-level socioeconomic differentials are far from being the whole explanation for them.

Physical environment might be a key determinant of the spatial distribution of health and disease.⁴ However, it has been often ignored by research on inequalities. Where it has been included, the focus has tended to be on harmful factors (e.g. pollution and climate extremes) ignoring the beneficial ones (e.g. green space and mild climate). Also, researchers have typically analyzed single exposures, ignoring the fact that pathogenic exposures rarely occur in isolation, and have mostly considered acute effects, overlooking the potential chronic effects.⁵ We hypothesize that a wide range of harmful and beneficial factors, interacting with each other and with socioeconomic, cultural and individual characteristics, might shape the geographies of health.

Recently, researchers from United Kingdom (UK) and New Zealand (NZ) looked at the implications of physical environmental for spatial inequalities in health. They followed the principles used to build well-known socioeconomic deprivation indexes—England,⁶ Scotland,⁷ Wales⁸ and Northern Ireland⁹ indices of multiple

deprivation, which recently started to integrate variables of the physical environment such as air pollution, as well as Carstairs¹⁰ and Townsend.¹¹ The outcome was the creation of the Multiple Environmental Deprivation Indexes (MEDIx) specific to UK and to NZ.^{12–17} These indexes, together with socioeconomic deprivation, contributed to a better understanding of spatial inequalities in health within these countries. Indeed growing evidence suggests the effect of socioeconomic and environmental deprivation on health inequalities cannot be detached; they need to be studied within an ‘environmental justice’ framework to assess whether most socioeconomically deprived populations are exposed to harmful physical environments and vice versa.¹⁸ Environmental justice can be defined as the fair treatment and meaningful involvement of all people, regardless their demographic and socioeconomic profile, with respect to the development, implementation and enforcement of environmental laws, regulations and policies.¹⁹

In Portugal, studies on health inequalities are sparse. Even so, several-fold differences in mortality and morbidity have been identified.^{20–23} Nevertheless, the strong regional differences in diseases, such as coronary heart disease, remain partially unexplained, possibly due to the restricted diversity (mostly economic and health resources) of the explanatory variables that have been considered.²⁰

On the basis of the research from the UK and NZ, we aimed to develop a Portuguese measure of multiple environmental

deprivation (PT-MEDIX). Our aim was also to assess how the choice of the environmental factors, datasets and methods of analysis should be adapted to the Portuguese idiosyncrasies without compromising comparability. This article describes how the PT-MEDIX was created, and how it is associated with risk of mortality in Portugal.

Methods

The development of PT-MEDIX followed the precedent set by the UK and NZ indexes and therefore had four stages^{12–17}:

- (1) Identify health-relevant environmental factors for Portugal.
- (2) Acquire and prepare datasets of such environmental factors.
- (3) Test associations between the environmental factors and health.
- (4) Construct the summary measure and assess its associations with health.

The term ‘environmental deprivation’ refers to physical environment that surrounds population and that includes external physical (e.g. climate), chemical (e.g. pollution) and biological (e.g. greenness) factors; social and cultural factors were excluded.¹³

Stage 1—identify health-relevant environmental factors for Portugal

To define whether an environmental factor was relevant for health, we used two criteria: (i) robust scientific evidence of a beneficial or harmful effect and (ii) at least 10% of the Portuguese population should be exposed to health impacting levels. This threshold was developed and adopted by the UK- and NZ-MEDIX research.^{13,16} While rather arbitrary, it nonetheless ensures that the included factors affect a reasonable proportion of the national population. In the UK work, for example, the threshold led to the exclusion of radon exposure, which affects a small and spatially restricted proportion of the UK population.

To identify which factors were related to health, an extensive literature review was conducted on key bibliographic databases—‘Pubmed’ and ‘WebOfKnowledge’, for studies about:

- Climate
- Traffic air pollution
- Industrial pollution
- Drinking water quality
- Ionizing radiation: ultraviolet B radiation (UVB) and radon
- Green space
- Noise.

We also sought Portuguese and Southern European-specific studies of the relationships between these factors and health.

Exposure to non-ionizing radiation (extremely low and radio frequencies) is rare in Portugal (<0.5% of the population), so we did not review the literature on that topic. We also excluded contaminated land, as datasets describing its distribution were unavailable.

A table summarizing the epidemiological evidence about the health impact of each factor is provided as Supplementary Material (see Supplementary table S1). Full reviews were written and are available from Centre for Research on Environment Society and Health and Institute of Public Health, University of Porto websites.^{24,25}

Stage 2—acquire and process datasets about the selected environmental factors

Portugal mainland territory is divided into 278 municipalities (average population=36 000), which are subdivided in parishes (average population=2500). The studies from UK and NZ were grounded in small geographic units: census area statistics wards (UK) and census area units (NZ). PT-MEDIX was constructed at

municipality level because (i) parish boundaries change frequently; (ii) socio-demographic data at parish level are available only for census years and (iii) mortality and health data are difficult to obtain at parish level due to confidentiality and, when accessible, they lack completeness and quality. To ensure our results were not biased by this decision, we replicated the study at parish level as far as possible. Key results remained unchanged.

We included only Portuguese-wide datasets, likely to be regularly updated, complete and of good quality. No country-wide dataset on noise exposure was found, leading to its exclusion. Similarly, no complete dataset on the duration of heat waves or cold spells was found. However, the distribution of the duration of extreme temperature events follows the geographical pattern of mean temperatures.²⁶ Available data on indoor radon exposure had outdated an inadequate geographical coverage, therefore was not considered. As almost all datasets were available for 2006, we centred our study around that year.

Table 1 describes the datasets used and the measures derived from them. Using a Geographical Information System, ArcGIS 10.2, we rendered each environmental dataset to municipalities. We calculated population-weighted means at municipality level to account for the unequal distribution of residents. An Europe-wide 1-km population grid³⁰ was used to calculate population-weighted exposures of air pollution, nitrates in private water supplies, climate and UVB.

Data for trihalomethanes (THM) in drinking water were already provided by municipality. To assess proximity to industries, a 3 km buffer (median radius found in the reviewed literature) around each facility was created and then intersected with the population grid to access the proportion of population within each municipality living within that radius. Population exposure to higher than recommended levels of THM was 8.3% but, being cautious, we included THM in our measure. Further, although nitrates in public water supplies are almost absent, high nitrate levels are quite common in private water sources in densely populated areas with intensive agriculture. In 2011, 13% of the Portuguese households were not connected to public water supplies, but population often uses both private and public supplies, meaning a much higher proportion of people using private water sources and, consequently, exposed to its contaminants. Again, cautiously, nitrates in private water supplies were included in analysis.

Stage 3—test associations between selected environmental factors and health

To validate the previous selection, a preliminary analysis was conducted to confirm whether each of the environmental factors had expected associations with health outcomes, after adjustment for sex, age and socioeconomic deprivation. Environmental factors were included in the development of the PT-MEDIX if significantly associated with mortality. When they were strongly and significantly correlated, the factor with the strongest effect and most scientifically documented was kept in the summary measure.

Mortality data were obtained from the Statistics Portugal for a 5-year period (2006–2010) and computed by municipality, gender, age group (0–14, 15–24, 25–34, 35–44, 45–54, 55–64, 65–74, 75–84, ≥85) and cause of death [all-cause mortality excluding external causes (ICD-9 codes <800, ICD-10 A00–R99), cardiovascular disease (CVD, ICD-9 390–459, ICD-10 I00–I99) and cancer (ICD-9 140–239, ICD-10 C00–D48)]. Sex and age-specific population counts for the same geographic units and periods were also acquired. As no multiple index of socioeconomic deprivation is available for Portugal, we used the proportion of population of each municipality receiving social-financial support in 2011 (last census) as a measure of socioeconomic deprivation.¹⁷

To account for the large variance in the death counts, negative binomial regression models were used to model the association between each environmental factor and mortality, after adjusting

Table 1 Description of the datasets and municipality-level measures derived for the selected environmental factors

Environmental factor	Source	Description	Processing	Municipality-level measure	Year(s)
Air pollution	Airbase from European Environment Agency (EEA) ²⁷	Annual averages of: particulate matter (PM ₁₀ and PM _{2.5}), ozone (O ₃), nitrogen dioxide (NO ₂), sulphur dioxide (SO ₂) and carbon monoxide (CO)	EEA provide 10 km grids for PM ₁₀ , PM _{2.5} and O ₃ , exclusively; 10 km grids for the remaining pollutants were derived from station data (also from EEA) and interpolated using kriging.	Population-weighted mean of each pollutant	2006
Green space	Coordination of Information on the Environment (CORINE) Land Cover Data ^{28,29}	Map of land cover (44 classes)	Twenty-seven classes corresponding to green areas were selected.	Total percentage of green space	2006
Climate	Portuguese Institute for Ocean and Atmosphere (Instituto Português do Mar e da Atmosfera, IPMA) and Spanish Meteorology Agency (Agencia Estatal de Meteorología, AEMET)	Climatological averages by station (<i>n</i> = 74): annual mean (year), warmest month (July), maximum and coldest month (January) minimum temperatures (°C)	1 km grids for each temperature were derived using kriging as interpolation method	Population-weighted mean of each climate variable	1970–2000
UVB Index	Portuguese Institute for Ocean and Atmosphere (IPMA, Instituto Português do Mar e da Atmosfera)	Average UVB index (unitless) Geographical Information System grid with a spatial resolution of 0.5° (~50 km) obtained by satellite images (clean sky)	–	Population-weighted mean	2003–2012
Industrial facilities	European Pollutant Emission Register (EPER)	Location of the waste management sites, mineral and chemical manufacture, metal production and processing facilities and combustion installations.	–	Proportion of population living within 3 km of some facility	2008
Drinking water quality	Public water supplies Regulator Institute of Water and Waste (Instituto Regulador de Águas e Resíduos, IRAR)	Annual median by municipality For each parameter: magnesium (Mg), calcium (Ca), nitrates (NO ₃ ⁻), aluminum (Al), arsenic (As), manganese (Mn), lead (Pb) and THM	–	Median of each parameter	2011
	Private water supplies (ground water from wells, boreholes and springs) Water Resources Information National System (Sistema Nacional de Informação de Recursos Hídricos, SNIRH).	Median by station for nitrates (NO ₃ ⁻)	1 km grids were derived using kriging as interpolation method		1997–2012

for socioeconomic deprivation, age and sex structure of the population and interaction between socioeconomic and environmental deprivation (PT-MEDIX). The age- and sex-specific population of each municipality was included as exposed population (model offset). Results were expressed as mortality rate ratios (MRRs) and corresponding 95% confidence intervals (CIs).

Sulphur dioxide (SO₂) was uncorrelated with all mortality causes (MRR ~1), so that it was not included in PT-MEDIX. The variables of temperature were highly correlated; therefore, we only kept mean temperature. The same issue applied to particulate matter (PM₁₀, PM_{2.5}) and ozone (O₃). We opted to retain PM₁₀, since reported effects on health are stronger and better studied.

Additionally, UVB and water hardness were excluded. The UVB was positively associated with each of the measures of mortality (e.g. MRR = 1.130, 95% CI: 1.105–1.155 for all-cause mortality); however, there is no biologic plausibility for an harmful effect of UVB on causes of death other than skin cancer (an infrequent cancer in Portugal³¹), especially because the UVB has little spatial variability in Portugal. Measures of water hardness presented a positive but weak relationship with CVD (MRR = 1.006, 95% CI: 1.005–1.007 for magnesium and MRR = 1.003, 95% CI: 1.002–1.003 for calcium). Lacking biologic plausibility for a 'harmful' effect of water hardness in CVD, those variables were excluded.

Stage 4—construct the summary measure and assess its association with health

To quantify the degree of multiple environmental deprivation in each municipality, we developed a single measure combining information on each environmental factor.

Ideally, we would have assessed whether each factor exceeded a health-relevant threshold within a municipality. However, the literature shows that there are no robust and consistent thresholds for any of them. We therefore identified municipalities as being exposed to a health-relevant amount of each factor, if situated in the highest quintile of that factor. Municipalities in the highest quintile of exposure received a score of +1 for harmful factors and –1 for beneficial factors. Harmful air pollution was defined as the highest quintile of 'any' of the air pollutants. The PT-MEDIX of each municipality resulted from the sum of these scores and ranged from –1 (least environmental deprivation) to +4 (most). No weighting of the factors was undertaken because there is no robust evidence by which to rank them according to health impact.

Once PT-MEDIX was built, negative binomial regression models were again used to estimate the association with mortality, adjusting for age-group, sex, socioeconomic deprivation and interaction between socio-economic deprivation and PT-MEDIX. To rule out the possibility that regression analysis might have led to spatially correlated errors, we mapped the residuals and calculated the Moran's I statistic; only a small and non-significant spatial autocorrelation in the residuals was observed.

We conducted several sensitivity analyses to insure that results were not solely determined by the method used or the time period of the mortality data. These were:

- (i) Trying multiple ways of computing the index.
 - (a) A uniquely positive index where all variables are considered detrimental, that is, a municipality in the lowest quintile of green space availability punctuated +1.
 - (b) An index based on extreme values of each factor, that is, municipalities in the 95th percentile of exposure received a punctuation of +1 and –1, for harmful and beneficial factors, respectively.
- (ii) Estimating the association between PT-MEDIX and health using mortality data of 2003–2005.

Results remained substantively unchanged despite the changes.

All models were run in R version 3.0.1 using 'mgcv' package.³²

Results

Spatial distribution of PT-MEDIX

Figure 1 depicts the spatial distribution of PT-MEDIX scores across Portugal. The highest scores were found in the large urban centres, the metropolitan areas of Porto and Lisboa and surroundings, the industrial area of Aveiro (coastline south of Porto) and the southern Alentejo and Algarve regions (figure 1). In contrast, the depopulated, rural and mountainous inner north and centre registered the lowest environmental deprivation. No clear latitudinal/longitudinal trend was observed in PT-MEDIX spatial distribution.

One third of the municipalities were classified into the intermediate category, having neither high exposure to harmful nor to beneficial factors. Twelve percent were placed in the least environmentally deprived group (depopulated and mountainous areas where 3% of the population lives), whereas only 5% were placed in the category of highest environmental deprivation (with 20% of the population).

Table 2 lists median values of the included environmental factors according to PT-MEDIX score—as it rises, an increase in the median exposure to the different factors is observed.

PT-MEDIX and health

For all-cause and cancer mortality, the more environmentally deprived municipalities showed significantly higher MRRs (using intermediate level of environmental deprivation as reference), even after adjustment for confounders (table 3). Associations with CVD were positive but did not reach statistical significance.

Comparing with those in the intermediate category, less environmentally deprived municipalities showed lower MRRs and more deprived municipalities showed higher MRRs: MRRs for all-cause mortality were 0.962 (95% CI: 0.934–0.991) and 1.209 (95% CI: 1.086–1.344), in the least and most deprived municipalities respectively, and for cancer, 0.957 (95% CI: 0.911–1.006) and 1.345 (95% CI: 1.123–1.598). Putting it in absolute terms, the most environmentally deprived municipalities had 6300 extra deaths per year when compared with the reference category (MEDIX = 0). For cancer, the dose–response relationship is particularly evident: the highest MRRs were found in areas with a score of +3 or +4.

Discussion

The UK/NZ approach to calculating an MEDIX was successfully transferred to Portugal. We identified factors in the physical environment that were related to population's health in Portugal, which, combined, resulted in an ordinal index which we used to classify municipalities according to the level of multiple environmental deprivation. Significant and plausible associations with all-cause, cardiovascular and cancer mortality were found even after adjusting for demographic and socioeconomic confounders. Associations with cancer were stronger and seemed to follow a dose-response pattern.

By creating PT-MEDIX, we answered international calls for more evidence-based, ready-to-use and understandable multivariate indexes.³³ Multivariate indexes are valuable tools for policy makers and other stakeholders. They contribute to a better understanding and monitoring of multidimensional phenomena. When aspects of environment are assessed and regulated as individual components, it is likely that the possibility of improving health via intervention is reduced. We run the risk of fixing one problem, ignorant of the fact that many others exist in the same location. The understanding that there are multiple aspects of environmental deprivation, which might require more than one policy intervention, is therefore vital.

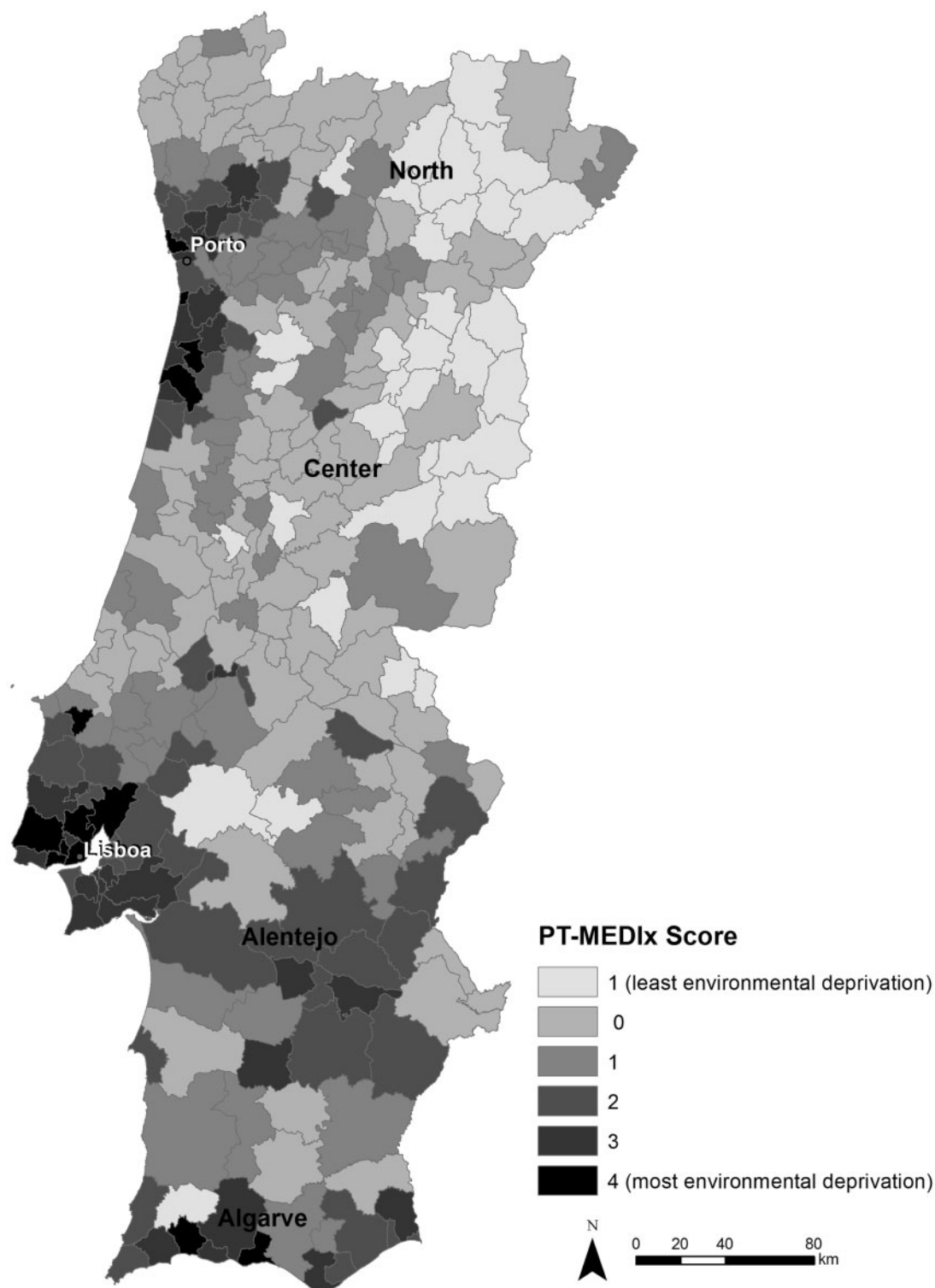


Figure 1 Spatial distribution of PT-MEDix scores across Portugal

Such indexes also help to identify populations which are at relatively greater or lower risk.

The major strength of this study lies on the fact that we succeeded to collect a large amount of data and developed a comprehensive environmental deprivation index for Portugal which can now be compared with UK/NZ indexes. Moreover, as with the development of MEDix in the UK/NZ, we used clear methods, allowing its reproduction in different contexts. The sensitivity analyses help reassure that the results are not unduly driven by the methods selected—the choice of the geographical unit, the temporal reference of mortality data and the way environmental factors were combined, did not

meaningfully alter the key results. Moreover, we saw that environmental deprivation represents a crucial health determinant, capable of causing an annual excess of 6000 deaths.

Although our methodology was deliberately similar to the UK/NZ indexes, the datasets, variables and final results are distinct (see Supplementary table S2). For UK-MEDix, eight variables (SO_2 , nitrogen dioxide, PM_{10} , carbon monoxide, average temperature, UVB, green space and industries) were considered, in NZ-MEDix four (PM_{10} , average temperature, UVB and green space) and in PT-MEDix, eight. UVB is unrelated with Portuguese mortality, contrasting with a strong protection found in UK and NZ, probably due

Table 2 Characteristics of the MEDIx scores—median values of the environmental factors for each PT-MEDIx score

	PT-MEDIx score					
	−1 (least environmental deprivation)	0	+1	+2	+3	+4 (most environmental deprivation)
No. of municipalities (%)	34 (12.2)	93 (33.5)	60 (21.6)	45(16.2)	33(11.9)	13(4.7)
Population (2006) (%)	337 085 (3.4)	1 645 962 (16.4)	2 067 310 (20.6)	1 723 042 (17.2)	2 234 933 (22.3)	2 017 506 (20.1)
Environmental factors						
PM ₁₀ ^a	12.97	15.78	17.78	18.85	21.67	22.91
NO ₂ ^a	18.64	20.03	22.01	23.08	26.97	29.19
CO ^a	168.13	165.65	192.04	191.70	232.89	246.34
Mean temperature (°C) ^b	13.07	15.05	15.33	15.73	15.77	16.01
Industry proximity (%) ^c	0.00	0.73	3.99	7.79	62.51	65.54
Green space (%) ^d	99.25	98.06	96.34	95.01	78.26	73.08
THM ^e	5.00	5.00	9.28	19.20	32.30	43.00
NO ₃ ^f	7.00	8.00	11.00	24.00	27.00	29.00
Deprivation ^g	2.95	3.73	4.07	4.46	4.63	4.52

a: Annual average (µg/m³).

b: Annual average temperature (1970–2000).

c: Proportion of municipality's population living within 3 km of an industrial facility.

d: Proportion of the municipality's area covered with green space.

e: THM annual median (µg/m³).f: Annual median (mg/m³).

g: Proportion of population of each municipality receiving social-financial support in 2011.

Table 3 MRRs (and corresponding 95% CIs) for the association between PT-MEDIx and mortality, adjusted for covariates (age, sex, socioeconomic deprivation^a and interaction between socioeconomic deprivation and PT-MEDIx)

	All-cause	Cardiovascular disease	Cancer
PT-MEDIx			
−1 (least deprived)	0.962 (0.934-0.991)**	0.924 (0.880-0.969)**	0.957 (0.911-1.006)
0	1.000	1.000	1.000
+1	1.024 (0.979-1.072)	1.115 (1.038-1.198)**	1.005 (0.930-1.084)
+2	1.012 (0.970-1.056)	1.032 (0.962-1.106)	1.147 (1.078-1.220)***
+3	1.199 (1.083-1.327)***	1.106 (0.929-1.312)	1.312 (1.100-1.552)**
4 (most deprived)	1.209 (1.086-1.344)***	1.071 (0.892-1.281)	1.345 (1.123-1.598)***
−2 × log likelihood	108 130.3	70 747.0	72 202.9
Likelihood ratio test (P value) ^b	<0.001	<0.001	<0.001

*0.01 < P value < 0.05.

**0.001 < P value < 0.01.

***P < 0.001.

a: Proportion of population of each municipality receiving social-financial support in 2011.

b: Chi-square test to compare the final model (with PT-MEDIx) and the incomplete model (without PT-MEDIx).

to the smaller latitudinal extent of Portugal. Temperature had a positive association with mortality in Portugal, whereas in NZ and in UK, the association went in the opposite direction. This was not surprising as in Portugal temperature rarely reaches life-threatening lows, but heat extremes are frequent and unquestionably harmful.^{34,35} Contrasting with UK and NZ, where no measure of drinking water quality was available, THM and nitrates showed strong and significant associations with cancer mortality. If NZ-MEDIx has a balance of detrimental/beneficial factors, in PT-MEDIx we included considerably more detrimental factors, with just one beneficial characteristic (green space). This contributed to the differing ranges of the indexes. Moreover, we were not able to follow NZ's strategy of including health-related behaviours as confounders due to data unavailability. As in NZ, we found a higher proportion of the country's population living in the most environmentally deprived areas than was found in UK. This was not surprising. The internal regions of Portugal, the least environmentally deprived, experienced massive depopulation since the 1980s. The UK has not experienced such large population shifts in recent history.

As in the UK/NZ analyses, in Portugal, the effect of environmental deprivation on health was progressive and moderate.^{16,17} Still, areas

with disadvantaged physical environment experienced significantly higher risk of mortality.

This study had several limitations. Because of data unavailability, we could not include environmental factors such as noise and radon exposure. Results might change with their inclusion. Although we tried to include accurate and contemporary datasets, the presence of inaccuracies remains a possibility. Establishing a causal relationship between PT-MEDIx and health was also not possible from this cross-sectional study design.

There are three particular problems with cross-sectional data and design in this study. (i) PT-MEDIx is a snapshot of the environmental characteristics of each municipality in a single time period, which might not correspond to the environmental characteristics to which the population was exposed during lifetime. (ii) We assumed place of the residence as the area where health-relevant exposures occur, but individuals might have spent much time in another area. (iii) We could not adjust our analysis for other crucial health factors, such as physical activity, smoking or obesity. However, these factors are linked to socioeconomic deprivation and control for deprivation may have reduced their confounding influence. A further weakness is that, as in the UK/NZ analyses, we treated all factors as equal contributors to environmental deprivation. This might be

unrealistic, but without robust evidence, any weighting would be arbitrary. Finally, we chose municipalities as geographical units for practical reasons. It is highly likely that these units do not capture very well environmental exposures with high spatial variability, such as green space or pollution. The unavoidable integration of gridded and areal data might also have obscured the true spatial distribution of the environmental exposures. Gridded data had greater resolution than polygons (municipalities); the only exception was UVB, whose grid cell size was larger than the municipality polygons; however, because of the small spatial variability of UVB, matching it with the polygons does not represent a major problem.

In conclusion, this work resulted in an evidence-based and understandable indicator of environmental deprivation for a southern European nation. This measure could help to comprehend the poorly understood spatial inequalities in health in Portugal; to untangle the complex pathway that links individual-characteristics, socioeconomic and physical environment and to identify vulnerable populations and address their specific problems. PT-MEDIX could be used by both academics and policy makers. Despite being moderate, associations between environmental deprivation and health cannot be ignored, as they affect a large number of people. After being built for three distinct countries, we encourage other teams to develop similar environmental deprivation indexes and test their validity and utility in explaining health inequalities. Such work will enhance debate about the role of physical environment in health inequalities.

Supplementary data

Supplementary data are available at *EURPUB* online.

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Conflicts of interest: None declared.

Key points

- Spatial inequalities in health have been identified but the contribution of physical environment has been largely ignored.
- We developed an evidence-based and understandable indicator of environmental deprivation for Portugal, including for the first time water quality parameters.
- Significant and plausible associations between this indicator and all-cause and cancer mortality were found.
- Hopefully, this measure could assist to better understand spatial inequalities in health; to untangle the complex pathway that links individual characteristics, socioeconomic and physical environment and to identify vulnerable populations and address their specific problems.

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Short Report

A prospective study of occupational status and disability retirement among employees with diabetes in Denmark

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The aim of this study was to examine the extent and distribution of disability retirement among people with diabetes in the workforce. Using four population registries, the study examined the relative rates of disability retirement among employees in Denmark over a 10-year period. The findings highlight that the risk of disability retirement increases as occupational status decreases. With an ageing workforce and increasing prevalence of diabetes, it is important to target primary, secondary and tertiary prevention to the groups that need it most in attempts to prolong the working lives of individuals.

Introduction

Type 1 (T1DM) and type 2 diabetes mellitus (T2DM) have previously been shown to have a significant impact on the risk of disability retirement.^{1–4} The aim of this study was to estimate the proportion of disability retirements, among employees with diabetes, which could be attributed to occupational status. This perspective was considered important since both incident diabetes⁵ and disability⁶ are marked by a social gradient. Obtaining detailed information on the relationship between diabetes, disability retirement and occupational status is, therefore, undertaken with a view to informing efforts to tackle the problem of early retirement⁷ and, in particular, early retirement among people with diabetes. Utilizing the population registries in Denmark provides strong and comprehensive data upon which these relationships can be delineated and understood.

Methods

The study used a dataset generated by combining variables from four national registries—the central person registry (CPR), the Danish National Diabetes Registry (DNDR),⁸ the employment classification

module (AKM) and the National Registry of Social Transfer Payments (DREAM) in Denmark.⁹ The CPR contains information on date of birth, gender, geographic residence, death and migrations for every person who is/has been an inhabitant of Denmark at some time since 1968. DNDR does not enable any distinction between T1DM and T2DM. Every resident of Denmark has a unique CPR number which provides the basis for linking individual data between different registries.

Occupational classification was derived from the SOCIO variable used by Statistics Denmark. SOCIO follows the categorization applied in the International Standard for the Classification of Occupations (ISCO 88) and, as such, classification will be based on the skills deemed necessary to undertake a specific occupation and not on formal education or income.

The study population comprised all employees in Denmark aged 20–59 years old registered in DNDR at baseline (1 January 2001). These people were followed from 1 January 2001 to 31 December 2010. The endpoint was disability retirement sometime during follow-up. All subjects were followed until any of the following events occurred: s/he reached the endpoint, s/he emigrated, s/he opted for early retirement, s/he turned 65 (65 being the official pension age during the study period), s/he died, the study